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Preschool stunting, age at menarche and adolescent height: a longitudinal study in rural Senegal

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Objective: To study the impact of preschool stunting on adolescent height and age at menarche in rural West Africa.
Design: A longitudinal, population-based study.
Setting: The Niakhar study area in Central Senegal.
Subjects: 1650 children aged 12–17 y with known height-for-age at the age of 2–5 y.
Main outcome measures: Adolescent height; mean age at menarche of girls estimated by the status quo method.
Results: The subjects were divided into three groups of preschool height-for-age: < -2, -2 to -1 and > -1 z-score of the NCHS reference. The mean height during adolescence differed significantly according to preschool height-for-age for both boys and girls ($P < 0.001$). Relative risk of adolescent stunting according to preschool stunting varied from 2.0–4.0 depending on age and sex. Estimated mean age at menarche was 17.2 (95% fiducial confidence interval: 16.6–18.7), 16.5 (16.1–17.2) and 15.6 (15.2–16.0) y, respectively, for the three groups of preschool height-for-age ($P < 0.001$). Mean increment from age 5 y to adolescence did not differ significantly among the boys according to preschool stunting, but among the girls aged 16–17 y, the increment was higher for those who had been stunted during preschool life ($P < 0.01$).
Conclusion: Some evidence of catch-up growth between the ages of 5 and 17 y was found for stunted girls. The significant delay in sexual maturation of the stunted girls suggests that stunted children of both sexes have a possibility of catch-up growth after the age of 17 y.
Sponsorship: The preschool study was supported by the EEC (TSD-036).
Descriptors: stunting; catch-up growth; adolescence; menarche; sexual maturation; Africa

Introduction

Studies of the long-term impact of preschool linear growth retardation on a child's final height, intellectual development and, for females, reproductive health are important in order to assess the handicap encountered by stunted children living in developing countries. Follow-up studies which compare final height among children from the same area according to their preschool height are preferable to cross-sectional studies that compare adolescent and adult heights of groups from different settings, because the importance of genetic and ethnic differences in growth during adolescence is not well known (Martorell *et al*, 1994). But longitudinal studies linking preschool height status to adolescent or adult height are scarce, and results vary greatly among the few published studies.

In rural Hyderabad, India, final height was positively correlated with height at the age of five years, but some degree of catch-up growth occurred, since the height increment from age 5–18 y was 6.4 cm higher for girls with a height-for-age less than -4 z-scores of the NCHS reference than for those with a mean z-score superior to -2 (Satyanarayana *et al*, 1981). Among boys, the height increment from 5–18 y of age was only 1 cm higher for the boys with a preschool height-for-age below -4 than for those with a height-for-age above -2 (Satyanarayana *et al*, 1980). However, when the boys were followed until total arrest of growth, the height increment was 5.5 cm higher for the group of boys who were smallest at 5 y compared to the tallest (Satyanarayana *et al*, 1986). The most severely stunted girls caught up almost half of their preschool height deficit compared to the least stunted, while the most stunted boys caught up about one-third of their deficit.

In rural Nigeria, West Africa, a cohort of children was divided into four groups of height at the age of 5 y and followed until the age of 17 y (Hussain *et al*, 1985). The height differences remained nearly identical during adolescence for both sexes. The growth spurt of the most stunted girls was delayed by about two years compared to the least stunted. At the age of 17 y, the mean height of all girls was still 6 cm higher than the mean height of the boys, indicating that linear growth was far from being completed. The impact of preschool stunting on final height was therefore unknown.

In rural Guatemala, the length at three years of age was very strongly associated with the height at the age of 18–26 y (Martorell *et al*, 1990, 1992), while the height increment from 3 y to adulthood was independent of length at the age of 3 y. Therefore, the most stunted children at preschool age did not catch up at all during late childhood and adolescence compared to the least stunted.

In Alabama, USA, a group of 30 girls malnourished in early childhood was significantly shorter than a control group of well-nourished girls up to the age of 14.5 y, but not later on (Dreizen *et al*, 1967). Their height deficit was 9 cm at 12.5 y and 0.9 cm at 19 y, indicating a nearly

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complete catch-up during adolescence even though their environment had not changed.

The aim of this study was to assess the relationship between preschool linear growth retardation, used as an indicator of malnutrition during early life, and adolescent height and mean age at menarche of girls in a sample of adolescents aged 12–17 y and living in a rural area of Senegal, West Africa.

Subjects and methods

Study area

The Niakhar study area is a rural region located 150 km east for the capital city, Dakar. It has been under continuous demographic monitoring since 1983, when a central demographic and epidemiological database was set up. The population of 28 000 belongs to the Sereer ethnic group, and more than 90% are farmers who grow millet and groundnuts during the rainy season between July and October. Food shortage is prevalent during the months before the harvest from July–November. The infant mortality rate was 112 per 1000, and the mortality rate before the age of 5 y was 253 per 1000 from 1984–1991 (Chahnazarian *et al*, 1992). Mortality is subject to large seasonal variations among both infants and preschool children with 4–6 times more deaths per month from September–November than from January–April (Chahnazarian *et al*, 1992). A detailed description of the study area has been published previously (Simondon *et al*, 1996).

Preschool study

The data were collected during four surveys in May and November 1983 and in May and October 1984 as part of a study on the relationship between preschool nutritional status and risk of mortality (Garenne *et al*, 1987; Briend *et al*, 1989). A census was conducted from February–April, 1983, and birthdays of children were estimated by interviews with the mothers using calendars of local events. The population datafile was reactualized during a second survey from March–April 1984. All resident children born from January 1978 were eligible for inclusion into the study in 1983, while all those born from January 1979 were eligible in 1984. Children born since the last demographic census and children who had migrated into the study area were also included. The mean coverage rate of resident children was 82.5% (Garenne *et al*, 1987). Reasons for non-inclusion were absence of child and mother (4.6%), refusal of the mother to attend because of work-load etc (10.7%) and neonatality (2.2%). The mortality rate did not differ between included and non-included children from May 1983–1985 (Garenne *et al*, 1987). The measurements used in this analysis were the height of the children together with the height of the mothers, who were measured during the last three surveys only.

Adolescent study

All subjects born in the area between January 1978 and October 1984 (that is, eligible for the preschool study), who were still alive and had not emigrated in February 1995 were identified from the central database. The major part of the data collection was done from March to mid-May 1995 by visits to the homes of all eligible residents. Follow-up surveys were conducted during the rainy season from June–August for formerly absent subjects, mainly girls. These were measured in their homes as soon as their returnal had been notified by demographic field workers who visited all compounds weekly. Prior to the surveys, oral as well as written information about the project was communicated to all subjects or to their parents at their homes. Height was measured twice to the nearest mm using Harpenden anthropometers, and the mean was computed for analyses. The two teams of measurers were well trained, and measurements were standardized at the beginning of the study. Girls were asked whether they had experienced menstruation and whether they were pregnant. When a girl was unable to answer the questions, her mother was asked.

Statistical analyses

Preschool and adolescent height-for-age were computed using Anthro (CDC/WHO) and the NCHS reference. A total of 5864 children had been measured during the preschool study, but the 2340 children who had only been measured prior to the age of 24 months were not included in the analysis, since the prevalence of stunting increased up to two years in this study (Garenne *et al*, 1987). Among the remaining 3524 subjects, 282 had died, 748 had outmigrated and 2494 were still registered as residents in 1995. Significant preschool stunting was defined as a height-for-age of less than -2 z-scores of the NCHS reference during at least one survey between the ages of 24 and 59 months. Normal height status was defined by a height-for-age above -1 z-score in all surveys, while the remaining children were considered as 'mildly stunted'.

Characteristics of included subjects were compared to those of eligible subjects who could not be included in the adolescence study by chi-square test and Mantel–Haentzel chi-square test. Statistical analyses of height data used one- and two-way ANOVA and multiple linear regression (BMPD, BMDP Statistical Software Inc., Los Angeles, CA, USA). Six age groups were defined from 12 (12.0–12.9) to 17 (17.0–17.7) y. Relative risk of stunting at adolescence of children stunted at preschool age were computed using Epi Info (Epi Info Version 6, Centers for Disease Control, Atlanta, Georgia, USA) with 95% confidence interval limits.

Longitudinal analyses of growth considered only children measured at about five (4.5–5.4) y of age. This age group was chosen because the oldest children were followed up to the age of 17 y and were thus more likely to catch up. For these children, the height increment between preschool life and adolescence was compared for boys and girls separately by one-way ANOVA for three groups of age at adolescence: 15 y (14.5 –15.4), 16 y (15.5 –16.4) and 17 y (16.5 –17.4).

For girls, parameters of the distribution of age at menarche and their 95% fiducial confidence intervals were estimated by fitting normal, logistic and Gompertz cumulative distribution functions to status quo data by maximum likelihood (Proc Probit in SAS (SAS System, SAS Institute Inc., Cary, NC, USA, 1996), version 6.11 for Windows). Estimation by the normal distribution function is identical to the classical probit estimation (Eveleth & Tanner, 1990). Mean age at menarche was compared according to preschool height-for-age group by logistic regression (Proc Genmod), with menarcheal status as the response variable, and age and group as regressors.

Results

A total of 1657 adolescents with known height at the age of 24–66 months were present during the adolescence study. The height of seven subjects could not be measured

Table 1 Prevalence of significant, mild and no preschool stunting (%) of included and absent girls by age at the adolescence survey

	Included girls				Absent girls			
Age (y)	*N*	*Significant*	*Mild*	*None*	*N*	*Significant*	*Mild*	*None*
12	88	36.4	30.7	33.0	59	15.3	32.2	52.5*
13	137	37.2	35.0	27.7	99	33.3	31.3	35.4
14	121	38.8	30.6	30.6	121	36.4	31.4	32.2
15	145	25.5	29.7	44.8	133	30.8	24.8	44.4
16	91	31.9	26.4	41.8	104	25.0	32.7	42.3
17	26	38.5 **	30.8	30.8	14	50.0	21.4	28.6
Total	608	33.9	30.8	35.8	530	30.2	29.8	40.0

*$P < 0.05$ for difference between included and absent girls by chi-square test.
**$P < 0.05$ for difference among age groups for included girls by chi-square test.
Significant stunting: height-for-age z-score inferior to -2 at one or more visits.
No stunting: height-for-age z-score above -1 at all visits.
Mild stunting: remaining children.

correctly because of polio sequelae or other handicaps, so the analysis included 1650 adolescents, 1042 boys and 608 girls. The inclusion rate was higher for boys than for girls (60.1 *vs* 34.1%, $P < 0.001$), because higher proportions of girls had emigrated (29.1 *vs* 13.2%, $P < 0.001$) or were absent (29.7 *vs* 17.8%, $P < 0.001$). Eight percent of the children had died.

The absent adolescents were slightly older than those included among the girls (14.8 *vs* 14.6 y, $P < 0.05$) and the boys (14.9 *vs* 14.7 y, $P < 0.01$). Fewer absent than included girls had attended school (19.8 *vs* 28.3%, $P < 0.01$), while the opposite was true for the boys (50.0 *vs* 43.5% for absent and included subjects, respectively, $P < 0.05$). No significant differences were found in place of residence or mother's height for either boys or girls. These results were not changed when comparing the included adolescents to absent and emigrated subjects taken together. The prevalence of stunting during preschool life did not differ globally among present, absent or emigrated adolescents, either for girls or for boys. Only the 12-y-old absent girls had had a significantly lower prevalence of preschool stunting than their included counterparts (Table 1). The boys and girls who died between preschool life and adolescence had a higher prevalence of significant stunting than those who survived (53.9 *vs* 31.7%, $P < 0.001$).

For included children, the prevalence of preschool stunting was 33.0%. Boys and girls had similar prevalences, while children with a short mother (height < 160 cm, $n = 599$) had higher prevalences than children with a tall mother (38.9 *vs* 29.5% ($n = 957$), $P < 0.001$). The prevalence of significant stunting decreased slightly with age from 24–66 months, while the prevalence of normal height-for-age increased. Since the youngest adolescents were aged 2 y during the preschool study while the oldest were aged 5 y, the prevalence of *preschool* stunting also decreased significantly with increasing age among adolescents for both boys and girls (Table 1).

The mean prevalence of stunting at adolescence was 37.5% (95% CI: 35.1–39.8) for boys and girls taken together, but it varied widely with age and sex (Table 2). Among boys, the prevalence doubled from 12–17 y of age, while girls had a high prevalence at the age of 12 y and a much lower prevalence from the age of 15 y. Mean heights during adolescence were lower for children who were stunted at preschool age, both for boys and girls, after adjustment for age during adolescence (Figures 1 and 2, $P < 0.0001$). Among girls aged 15 y or more who had suffered no preschool stunting, mean height was close to the median of the reference (Table 3). The height curves of all three groups of boys fell off compared to the reference until 16 y of age (Figure 1), time at which boys stunted during preschool life had a mean height-for-age below -3.5 z-scores (Table 3).

Table 2 Prevalence (Pr) of stunting (haz < -2) at adolescence by sex and age (%) with numbers (N)

	Boys		Girls	
Age (y)	*N*	*Pr*	*N*	*Pr*
12	109	26.6	88	46.6
13	229	27.9	137	31.4
14	238	52.5	121	21.5
15	279	55.6	145	11.7
16	163	56.4	91	15.4
17	24	50.0 **	26	0.0 **
12–17	1042	45.8	608	23.2

**$P < 0.01$ for differences among age groups for either boys or girls by chi-square test.

Linear regression analyses showed that preschool height and age, sex and adolescent age accounted for 57% of the variance in adolescent height ($n = 1556$). The addition of mother's height improved the prediction slightly, but significantly ($R^2 = 0.58$, $P < 0.01$). The risk of adolescent stunting was significantly higher in case of preschool stunting for both boys and girls (Table 4).

A longitudinal analysis of growth in height according to preschool height status was performed for the children measured at the age of 4.5–5.4 y. Mean adolescent heights differed very significantly according to the group of preschool height-for-age for both boys (Table 5) and girls (Table 6). Among boys aged 15 and 16 y, the mean height increment between early childhood and adolescence tended to be greater for those with normal preschool height than for those with mild or significant stunting, but the differences were not significant. Among girls aged 15 y, the mean height increment did not vary significantly according to preschool height-for-age, but for those aged 16 or 17 y, it was highest for the stunted girls, and the differences among the three groups were significant (Table 6). These differences remained significant when adjusting for the migration status of girls (returnal from migration or not). The height difference between the most stunted and least stunted was about 12 cm at the age of 5 y in both sexes and about 13 cm for adolescent boys. Among adolescent girls, it varied from 10.0 cm for 15-y-olds to 6.2 cm for 17-y-olds.

Table 3 Mean height-for-age z-score at adolescence according to the degree of preschool stunting

	Boys			Girls		
Age (y)	*Significant*	*Mild*	*None*	*Significant*	*Mild*	*None*
12	−2.08 (45)	−1.42 (39)	−0.85 (25)	−2.80 (32)	−1.70 (27)	−1.15 (29)
13	−2.08 (79)	−1.58 (72)	−1.14 (78)	−2.02 (51)	−1.39 (48)	−0.86 (38)
14	−2.70 (83)	−2.06 (83)	−1.16 (72)	−2.01 (47)	−0.91 (37)	−0.42 (37)
15	−2.91 (88)	−2.20 (88)	−1.43 (103)	−1.51 (37)	−1.16 (43)	−0.18 (65)
16	−3.53 (36)	−2.44 (62)	−1.35 (65)	−1.43 (29)	−0.77 (24)	−0.21 (38)
17	−3.48 (7)	−1.70 (10)	−1.65 (7)	−0.84 (10)	−0.59 (8)	+0.29 (8)

Number of subjects in parentheses.
Significant preschool stunting: height-for-age z-score inferior to −2 at one or more visits.
No preschool stunting: height-for-age z-score above −1 at all visits.
Mild preschool stunting: remaining children.

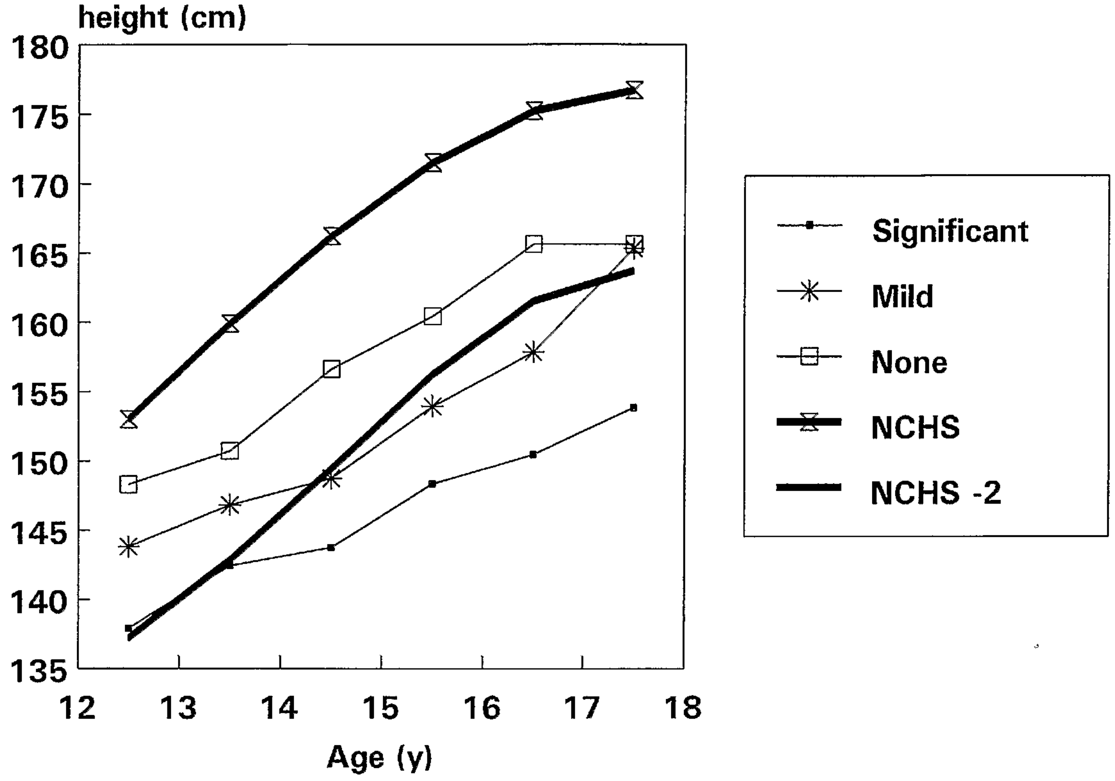

Figure 1 Mean height of adolescent boys by age for three groups of preschool height-for-age significantly stunted (preschool height-for-age below −2 z-scores of NCHS reference during at least one survey), not stunted (preschool height-for-age above −1 z-score of the reference at all surveys) and mildly stunted (remaining children), together with medians and −2 z-score values of adolescent height-for-age in the NCHS reference (WHO, 1983).

Status quo data for menarche were available for 599 girls out of 608. The proportion of post-menarcheal girls was 23.7% when all girls were considered together, and 15.0, 16.1 and 40.7% for significantly stunted, mildly stunted and non-stunted, respectively. The three models (normal, logistic and Gompertz distributions) fitted the status quo data equally well and yielded very similar results. By fitting a logistic regression, mean age at menarche was estimated at 17.2 y (95% CI: 16.6–18.7) for girls significantly stunted during preschool life, 16.5 y (CI: 16.1–17.2) for mildly stunted girls and 15.6 y (CI: 15.2–16.0) for girls without preschool stunting. The three groups differed significantly ($P < 0.001$), but nested contrasts showed that only the girls without preschool stunting differed significantly from the other two groups (stunted *vs* mildly stunted $P = 0.40$), stunted and mildly stunted *vs* not stunted: $P < 0.001$). However, the mean age at menarche of significantly stunted girls differed from that of the other girls taken together ($P < 0.01$).

Discussion

This study confirms the existence of a strong relationship between preschool height-for-age and adolescent height, as already described for rural Nigerian adolescents (Hussain *et al*, 1985), Indian boys (Satyanarayana *et al*, 1989), Guatemalan adolescents (Johnston & MacVean, 1995) and West Indian adolescents (Galler *et al*, 1985). Clearly, the height deficit accumulated during the first years of life by these Senegalese children was not caught up during late childhood or early adolescence, since the increment between 5 and 15 y of age did not differ according to preschool height in either boys or girls. However, some catch-up growth occurred among girls during the second half of adolescence, since those stunted at preschool age had a significantly greater height increment between 5 and 16–17 y of age than those who were mildly growth retarded or of normal preschool height.

In this study, the children were measured at various ages during preschool life as well as during adolescence, while

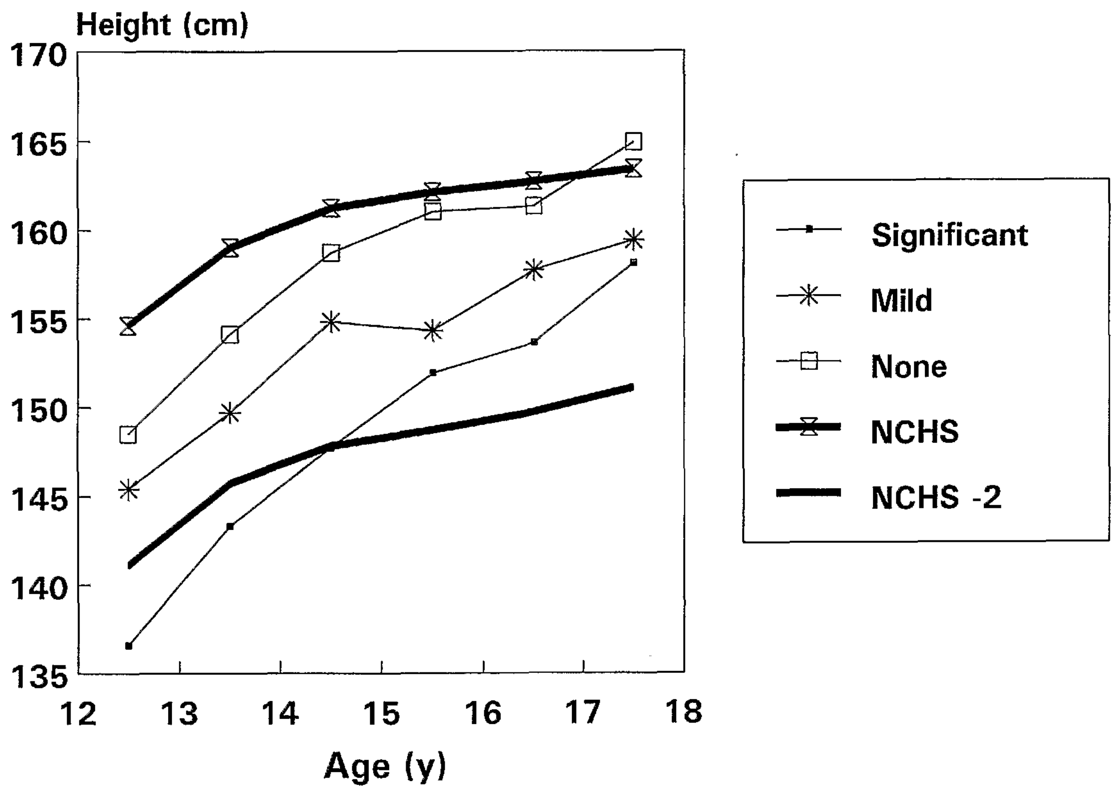

Figure 2 Mean height of adolescent girls by age for three groups of preschool height-for-age significantly stunted (preschool height-for-age below −2 z-scores of NCHS reference during at least one survey), not stunted (preschool height-for-age above −1 z-score of the reference at all surveys) and mildly stunted (remaining children), together with medians and −2 z-score values of adolescent height-for-age in the NCHS reference (WHO, 1983).

Table 4 Relative risk (RR) of stunting (haz < −2) at adolescence of children stunted at preschool age with 95% confidence intervals (CI)

		Preschool stunting			
Sex	*Age (y)*	*Significant*	*Mild or none*	*RR*	*CI*
Boys	12–14	139/207	79/369	3.1	2.5–3.9
	15–17	114/131	145/335	2.0	1.8–2.3
Girls	12–14	75/130	35/216	3.6	2.5–5.0
	15–17	19/76	12/186	4.0	2.0–7.8

Significant preschool stunting: height-for-age z-score inferior to −2 at one or more visits.
No preschool stunting: height-for-age z-score above −1 at all visits.
Mild preschool stunting: remaining children.

Table 5 Height at five years, height at adolescence, and height increment from five (4.5–5.4) y to adolescence according to degree of preschool stunting among boys

Adolescent age (y)	*Stunting*	*n*	*Height at 4.5–5.4 y mean ± s.d.*	*Adolescent height mean ± s.d.*	*Increment mean ± s.d.*
14.5–15.4	Significant	51	96.2 ± 3.5	146.8 ± 7.8	50.6 ± 6.8
	Mild	47	102.7 ± 2.0	153.0 ± 6.7	50.3 ± 6.6
	None	50	107.2 ± 2.4	159.3 ± 7.5	52.1 ± 7.1
			***	***	NS
15.5–16.4	Significant	40	95.5 ± 3.9	150.1 ± 7.6	54.6 ± 7.8
	Mild	65	102.0 ± 1.7	155.7 ± 5.9	53.7 ± 6.3
	None	75	107.5 ± 2.7	163.7 ± 6.7	56.2 ± 6.3
			***	***	NS
16.5–17.4	Significant	19	96.2 ± 3.3	151.8 ± 7.5	55.6 ± 7.1
	Mild	30	102.3 ± 2.1	161.4 ± 7.3	59.1 ± 7.0
	None	31	107.7 ± 3.3	165.1 ± 6.3	57.0 ± 5.9
			***	***	NS

***$P < 0.001$; NS: difference not significant, among the three groups by one-way ANOVA.
Significant preschool stunting: height-for-age z-score inferior to −2 at one or more visits.
No preschool stunting: height-for-age z-score above −1 at all visits.
Mild preschool stunting: remaining children.

Table 6 Height at five (4.5–5.4) y, height at adolescence, and height increment from five (4.5–5.4) y to adolescence according to degree of preschool stunting among girls

Adolescent age (y)	*Stunting*	*n*	*Height at 4.5–5.4 y mean ± s.d.*	*Adolescent height mean ± s.d.*	*Increment mean ± s.d.*
14.5–15.4	Significant	17	95.7 ± 4.0	150.9 ± 5.5	55.3 ± 5.6
	Mild	17	100.8 ± 1.8	153.6 ± 8.8	52.8 ± 8.2
	None	19	107.0 ± 3.3	160.9 ± 6.1	53.9 ± 6.3
			***	***	NS
15.5–16.4	Significant	32	94.3 ± 4.2	152.5 ± 5.7	58.2 ± 5.1
	Mild	29	101.5 ± 1.9	156.4 ± 5.2	54.9 ± 5.3
	None	48	107.3 ± 4.0	161.7 ± 4.2	54.4 ± 4.9
			***	***	**
16.5–17.4	Significant	18	95.6 ± 3.5	156.0 ± 5.3	60.4 ± 6.0
	Mild	15	101.3 ± 2.0	158.4 ± 4.4	57.1 ± 4.4
	None	22	107.8 ± 4.2	162.2 ± 7.3	54.4 ± 7.0
			***	**	*

$^{*}P < 0.05$; $^{**}P < 0.01$; $^{***}P < 0.001$; NS: difference not significant, among the three groups by one-way ANOVA.
Significant preschool stunting: height-for-age *z*-score inferior to -2 at one or more visits.
No preschool stunting: height-for-age *z*-score above -1 at all visits.
Mild preschool stunting: remaining children.

previous studies considered preschool height at a given age, usually 5 y. The prevalence of stunting was not constant between 24 and 66 months, but decreased from 24 months. Therefore, the height deficit of 12-y-old stunted children could not be compared directly to that of 16-y-olds. However, because of the large number of subjects, comparisons of height deficits could be done for different age groups independently, and height increments from five years to adolescence were computed for a subgroup of children in order to allow for comparison with former studies.

The high rate of loss to follow-up after the preschool study was explained partly by the high childhood mortality at that time (29.8% of live-borns had died by the age of 5 y, Garenne *et al*, 1987). The children who died had a lower mean height-for-age than those who survived (Garenne *et al*, 1987; Briend *et al*, 1989), and this relationship between stunting and risk of death was also significant in our sample of children aged 2 y or more. Another important cause of loss to follow-up was absence from the home during the survey. In this community, a large proportion of girls work as maids in the capital city of Dakar for various durations during the dry season or during the whole year (Simondon *et al*, 1997). Migrating girls were included into the study as they visited their families during the rainy season, and half of the included girls were migrants. Labour migration to Dakar also explains the high level of out-migration among girls. Boys were absent from their homes for a variety of reasons. Some were shepherds, others were on shorter journeys and others again attended secondary school in town.

The relatively high proportion of absent girls raised concern that the results might apply only to the particular girls included into the analysis and not to all girls born in the study area. However, as shown in Table 1, no difference was found in the prevalence of preschool stunting between the included and absent girls (except for the 12-y-old who were not considered in the longitudinal analysis). Preliminary results from an ongoing longitudinal study also suggest that migration decisions are independent of the girl's height (E. Bénéfice, unpublished observations).

Many authors consider that the possibilities of catch-up growth are greater when the child moves to a more favorable environment during childhood or adolescence (Golden, 1994). But there is no indication that migration improves growth in height of these girls, since the height of included migrants did not differ from that of permanently residing girls, although the mean body weight and triceps and subscapular skinfolds were significantly greater among migrants ($P < 0.001$, Simondon *et al*, 1997). No impact was found on age at menarche either (16.3 y *vs* 15.8 y for migrants and residents, respectively, Simondon *et al*, 1997).

To our knowledge, this is the first longitudinal study to demonstrate an impact of preschool height on age at menarche in an African population. A cross-sectional study conducted in Kenya showed that poor rural girls had a mean age at menarche of 15.3 y *vs* 13.2 y for upper-class urban girls (Kulin *et al*, 1982). Similarly, a group of US girls malnourished since early childhood had a significant delay in mean age at menarche of 2.1 y compared to a group of well-nourished girls (14.5 y *vs* 12.4 y, Dreizen *et al*, 1967). In a longitudinal study in rural India, the difference in mean age at menarche between the most stunted and the least stunted was similar to that of the present study, although sexual maturation was less delayed (15.2 y *vs* 13.7 y, Satyanarayana & Nadamuni Naidu, 1979). In rural Guatemala, the difference between the most and the least stunted was smaller than in both Senegal and India (14.1 y *vs* 13.5 y, Khan *et al*, 1996), and mean age at menarche was lower than in Senegal. It thus seems that sexual maturation is less delayed by stunting in Central America than in other settings.

The relative risk of adolescent stunting in the case of preschool stunting was significantly greater than one in Senegal, but lower than in urban Guatemala, where it was 7.8 (95% CI: 4.4–13.7) at the age of 12–14 y for boys and girls together (computed from Johnston & MacVean, 1995). The lower relative risk in Senegal probably was due to the substantial delay in sexual maturation that induces adolescent 'stunting' in many Senegalese children, who were not stunted during preschool life.

Factors other than preschool height influenced adolescent height in this study. Maternal height remained linked to adolescent height when controlling for preschool height, which suggests that growth from preschool age to adolescence is associated with the mother's height. The father's height was not available, nor was any measure of socioeconomic status. This area is globally poor with chronic food insecurity, but some economic differences exist among households. Urban studies have shown a clear influence of socioeconomic status on mean age at menarche in Africa (Abioye-Kuteyi *et al*, 1997), but controlling for socioeconomic status did not modify the relationship between age at menarche and stunting at the age of three in rural Guatemala (Khan *et al*, 1996). The authors suggested that the influence of socioeconomic level on age at menarche was fully mediated through preschool height-for-age.

Mean height in the present study was characterized by progressive catch-up among girls for all groups of preschool height, and by an increasing deficit among boys compared to the NCHS reference. Although the mean height-for-age *z*-score of the boys decreased until 17 y of age, with a mean height 'deficit' of about 15 cm compared to the NCHS reference (Simondon *et al*, 1997), catch-up growth compared to Western populations will certainly occur in the boys at older ages, since the mean height 'deficit' of adult men is 4.3 cm compared to the 18-y-olds in the NCHS reference (172.5 cm, Simondon *et al*, 1996 *vs* 176.8 cm, WHO, 1983). For comparison, the mothers of the adolescents under study had a mean height 'deficit' of 3.0 cm compared to the NCHS reference (160.7 cm *vs* 163.7 cm, WHO, 1983).

Conclusions

Children suffering from preschool stunting were significantly shorter than other children during adolescence in this rural Sahelian setting. This height deficit, which was present before the onset of adolescence, tended to increase among boys up to 17 y of age, while it decreased significantly among girls. The stunted girls experienced a significant delay in age at menarche of 1.6 y compared to the tallest girls. Since some catch-up growth was found among girls aged 17 y, stunted adolescents might continue to catch up in height at older ages not covered by this study. Indeed, many authors have stressed that catch-up growth occurs through a prolonged growth period, rather than by greater peak height velocities (Satyanarayana *et al*, 1989; Cameron *et al*, 1994; Martorell *et al*, 1994). Further follow-up of this cohort, including measurements of final height, is necessary to assess the degree of catch-up growth during late adolescence of African children stunted during preschool life.

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